

SPACE MISSION OPERATIONS CONCEPT

Gael F. Squibb
Jet Propulsion Laboratory
California Institute of Technology
M/S 303-400
4800 Oak Grove Drive
Pasadena, CA 91109

Abstract. Developing a Mission Operations Concept for a space mission is a system engineering process. It involves multiple disciplines working together to describe the operational attributes of the flight and ground elements of the mission. A space mission operations concept emphasizes the way the mission will be operated and used (operational characteristic). This is done in terms that are understood by the operators of the system and the users (the recipients of the data from the system).

The Operational Attributes of a Mission are described by considering nine mission characteristics. These characteristics may be traded back and forth for cost and performance attributes of the mission. Developing a Mission Operations Concept is the process through which changes to mission requirements and/or design can be identified. These changes are usually made to lower the Mission Life Cycle Cost.

The inputs to the Mission Operations Concept include flight, ground and management functions.

Mission Operations Concepts are generated for nearly all space missions. It is a requirement in many project plans and in the RFPs that are generated by that plan. However, there is no definition of what is included in a mission operations concept, of what should be considered when generating this operations concept; of what the process is or of what the products are.

This paper will discuss the process of developing a space mission operations concept; the benefits of starting this system engineering task early; the necessary inputs to the process; and the products that are generated.

This paper is based on a chapter in a text book that will be published in March 1996 -- prior to the NCSC Conference. In addition, this process has just

started going through an international review that will result in an ISO Standard for a Space Mission Operations Concept checklist. This checklist will describe the inputs, and outputs required to conform to the ISO standard for a space mission operations Concept.

The paper will include that latest draft of the international standard checklist. It will explain the system engineering processes and the benefits of generating an operations concept during the study phase, early in the life-cycle of the project. It will then explain the importance of maintaining the operations concept throughout the life-cycle of the project.

What is a Mission Operations Concept?

A process which involves multiple disciplines, working together to describe the operational attributes of the flight and ground elements of the mission. It is similar to the development of a space mission concept except that the Mission Operations Concept is more detailed. It emphasizes the way the mission will be operated and used (operational characteristic). It does this in terms which are understood by the operators of the system and the users (the recipients of the data from the system).

Typically a Mission Operations Concept will be developed for each significant change to certain inputs to a Mission.

The Operational Attributes of a Mission are described by considering nine mission operations elements. These may be traded back and forth for cost and performance attributes of the mission.

It is through the process of developing a Mission Operations Concept that changes which will lower the Mission Life Cycle Cost can be identified.

The inputs to the Mission Operations Concept include flight, ground and management functions. They are described in detail in the section on inputs.

Why should a Mission Operations Concept be Developed?

Developing a Mission Operations Concept requires that different disciplines communicate with each other. These might include mission designers, S/C designers, payload designers, ground system designers, ground system operators, and recipients of data from the mission operations system.

The way that a space vehicle is finally operated is often different than what the designers of that space vehicle had in mind. Early communication among designers, operators and users of the data from the mission shortens the development time. This is due to fewer changes being required during the development or testing phases of the mission.

The process emphasizes areas in these disciplines where tradeoffs should be studied in order to minimize life-cycle costs and improve the return of information from the mission.

The operations concept, when documented, maybe used as a source of derived requirements on the development of functions of the mission operations system. Since the mission operations concept is responding to top-level mission requirements, it is easy to associate the derived requirements to the top-level mission requirements and to show requirements traceability during the design phase of the mission.

When the mission operations concept is performed early in the life cycle of a project, it often forces the resolution of design incompatibilities which would otherwise have to be solved (minimized) by operations developments or procedures.

When should a Mission Operations Concept be Developed and What should it cover?

Each Mission Concept should have a corresponding Mission Operations Concept. The two concepts may be developed in parallel. This process will save cycle time and reduce the conceptual and definition phase of a project. When developed in parallel, the Mission Operations Concept can quickly feed back any suggestions for reducing MOS costs into the development of the Mission Concept.

The earlier the Mission Operations Concept is conducted, the more influence the results will have on the development phase. This is because the interfaces and attributes of the inputs are less defined, and tradeoffs can be made. Table 1 shows how the input characteristics become finalized during the pre-project phases. By the time phase C/I is started, the Ground System Capabilities, **AND** the attendant Operations Staff are the functions that usually

change

The Operations Concept should be emphasized during Pre-phase A, Phase A, Phase B, and the early portions of Phase C/I. Under certain conditions it can even be conducted during Phase I: (Operations). When the Operations Concept is developed during phase C/I or I, the only changes that can be made are to the nine mission operations elements. This means changes will be made only to the Grounds System, to the People and Procedures, or to the Flight Software.

The Operations Concept should be updated during the life of the project. It is an excellent tutorial for new project personnel to gain an overview of the concepts that are being executed by the Mission Operations System.

Attributes of an Operations Concept

Developing an Operations Concept is a process which involves multiple disciplines, working together to describe the operational attributes of all functions of the system in the terms of the users of the system. It fosters a common understanding of processes among diverse elements of a project.

An operational concept stresses the way the system will be operated and used (operational characteristics). "This will be done in terms which are understood by the operators of the system **AND** the recipients of the data from the system. The process will focus on areas which are (1) not understood, (2) controversial, and (3) cost and performance drivers on the system.

Other areas which are identified and discussed during the process are documented for completeness. Developing an operations concept has also been shown to be a method of addressing system-level technical issues which cross separate funding boundaries.

To perform an operations concept, the key interfaces and attributes placed on the Mission Operations System must be identified. The process of developing an operations concept, identifies the key interfaces within the Mission Operations System. It is only at this point that the life cycle costs of a mission concept can be determined.

Table 1 Operational Concept Input Changes vs Mission Phase

Operations Concept Inputs	Project Phase				
	Pre A	A	H	C/D	E
Mission Scope, Objectives and Payload Requirements	C/F	F	F	F	F
Mission Plan	C	C	C/F	F	F
Mission Philosophies, Strategies and Tactics	C	C	F	F	F
Programmatic Constraints	C/F	F	F	F	F
S/C Capabilities and Characteristics	C	C	C/F	F	F
Flight S/W	C	C	C	C/F	F/F
Payload Capabilities and Characteristics	C	C	C/F	F	F
Ground System Capabilities and Characteristics	F/C	F/C	F/C	F/F	F/F
End-to-End information System Characteristics	C	C	C	F/F	F/F
End User Data Product Definition	C	C	C	F	F/F

F= input usually Frozen during this phase

C= input usually changeable or being defined during this phase

Table showing which of the above inputs are generally frozen as a function of the development phase } Pre-phase A through E;

C/F= Changeable but only for cause and with supporting rationale (usually cost or performance)

F/C= Existing Capabilities Defined New capabilities may be defined

F/F= Existing Capabilities Frozen, New capabilities may change, but only for cause and with supporting rationale (usually cost or performance).

Who should be involved in developing a Mission Operations Concept?

Thirteen functions have been defined which are used to describe a Mission Operations System. Eventually representatives of each of these functions need to be involved in the development of a mission operations concept. In the early phases (conceptual), one person will often represent several MOS functions,

A representative from one of the MOS functions will usually provide a person who is the facilitator and the keeper of the concept. This person often comes from the System Engineering or the Mission Planning function and is typically trained

in End-to-End information System Engineering. The Mission Concept and the Mission Operations Concept are closely linked. Some of the same individuals will be involved in both activities.

Inputs to a Space Mission Operations Concept

Nine different inputs should be considered when developing a space mission operations concept. All the inputs may not be known early in the life-cycle of a project, but reasonable assumptions should be made and documented. If these assumptions need to be changed later, the effect of the changed assumptions can be quantified.

The nine inputs that should be considered are:

1. Mission Scope, objectives and science requirements.
2. Mission Description.

¹ Cost Effective Space Mission Operations, McGraw Hill, 1996, Chapter 3, Mission Operations Functions.

3. Mission philosophies, strategies, and tactics.
4. Program constraints.
5. End-to-end information system characteristics
6. Ground-system characteristics
7. Payload Characteristics.
8. Spacecraft characteristics.
9. End-users' definition of needed data and data products.

The above inputs must be stated in terms that are meaningful to an operator.

DEVELOPING THE MISSION OPERATIONS CONCEPT

1. Identify the mission concept and the supporting space mission architecture
2. Determine Mission Operations functions which are to be performed.
3. Identify options for accomplishing these functions. Identify if the capability exists or if it must be developed.
4. Perform trades for items identified in step 3.
5. Develop operational scenarios for the functions determined in step 2 and the options selected in step 4.
6. Develop timelines for each scenario.
7. Allocate Steps of the scenario to Hardware, Software, or People.
8. Develop Data Flow Diagrams.
9. Characterize the organization and the team responsibilities.
10. Assess mission utility, complexity, and cost of mission operations.
11. Identify derived requirements and cost and complexity drivers. Negotiate changes with the mission concept.

The Mission Operations Concept Document

While developing the mission operations concept, keep the information in electronic form and available to all members of the project. This is

done so that people both inside the project and outside peers can have ready access to review and to critique the concept.

Document Organization and Structure

A suggested structure for the Mission Operations Concept document is given below. It is easier to review both mission operations concepts for different missions and mission operations concepts for different designs of the same mission, if a standard structure is followed.

The structure and content of most mission operations concepts written today reflect the experiences and background of those persons working on the concept rather than a systematic way of presenting the information.

- Introduction
- Scenarios
- Preliminaries
- People and procedure functions
- Hardware and software functions
 - Data Flow Diagrams
- Requirements and derived requirements

System Engineering and the Development of an Operations Concept.

The above sections describe the process and methodology of developing a mission operations concept

From an operations point of view, it is the most important operations document developed prior to launch

It is truly a system engineer's task to bring together the spacecraft developers and the ground system developers and operators. This engineer will lead the trade studies that are required during the early phases of the project design.

One way to understand the options available is to build a table which contains the operations functions that apply to the mission's ground data system and to the avionics. Identify whether the avionics (automated) or the ground system will do each function. If the function is on the ground, determine whether the hardware, software, or operators will complete the function.

Table 2 contains a table that maybe filled out. If a check goes in more than one place, describe which functions are done in each place and whether options exist. For those functions that are

done by operators, the system engineer leading the operations concept should identify what technology is required to move the function from an operator to an automated process on the ground or in the avionics.

MOS Function	Avionics	Ground } Hardware/ Software	Operators
Activity planning and development			
Mission Control			
Data transport and delivery			
Navigation planning and analysis			
Spacecraft planning and analysis			
Payload planning and analysis			
Payload data processing			

Table 2 Where to carry out mission operations functions

System Engineering and Trade Studies

The 101-level apportionment of functions between the ground and the flight avionics is done during the mission concept. With this as an input, the system engineer develops the mission operations concept. It is important to note that the mission concept, mission-operations concept and the design of the space and ground elements are closely related. As design proceeds, costs are always in the planners' mind. As designs for the space and ground system elements mature, trade studies are conducted to get the lowest cost and best design within certain cost caps. Whenever it appears that a cost cap will be exceeded and ways to meet the requirements within the ground system or operations area cannot be identified through trade studies, the next higher level of system engineering, the one that develops the mission concept must be invoked to find solutions within the total mission trade study space.

Figure 1 shows this process where operations trade studies and space-element trade take place within the life cycle process of the space element and the operations element. When these trade studies cannot find solutions that meet requirements and cost, then the mission trade studies must be conducted which addresses the mission concept and project requirements.

A Space Mission Operations Concept Standard

The basic information contained in this paper is being considered by one of the International Standards Organizations (ISO) Technical Committees as a potential international Standard. The standard, when approved will become a checklist that will list the considerations that must be considered when developing a space mission operations concept and the minimum topics that must be included in the contents of the document. The current draft of this standard will be available for review and comment at the symposium.

Conclusions

The development of a mission operations concept enables the system engineer to discuss changes to the mission concept based on quantitative data. The earlier the first mission operations concept is developed, the greater the leverage for minimizing life-cycle costs. It is important to keep the mission operations concept current because it is the best, top-level description of how the mission will be flown and of the tools that are needed to fly the mission.